# Fractal approaches to combat modelling

Dr Michael Lauren

# Report Documentation Page

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# Drivers

- Lack of models available. Simple “Lanchester” approaches the principal option
- Had a broad range of problems, including issues such as Recce and C2
- Agent-based models seemed like a good approach but not “Physics based”

# Origins of our approach

- The physics of weather: more detail does not give better answers
- Simple fractal models seem to better reproduce statistics of weather than supercomputers
- Differential equations do not seem to be able to describe complex systems
- Self-organisation important

# Hypothesis

- Assume combat is a self-organising system
- Further assume combat data can be characterised in terms of fractal dimensions
- Then, fractal dimension of combat data can be related to the attrition function

# Blue attrition

Function of:

- Number of Red
- Time
- Kill probabilities
- Fractal dimension of distribution

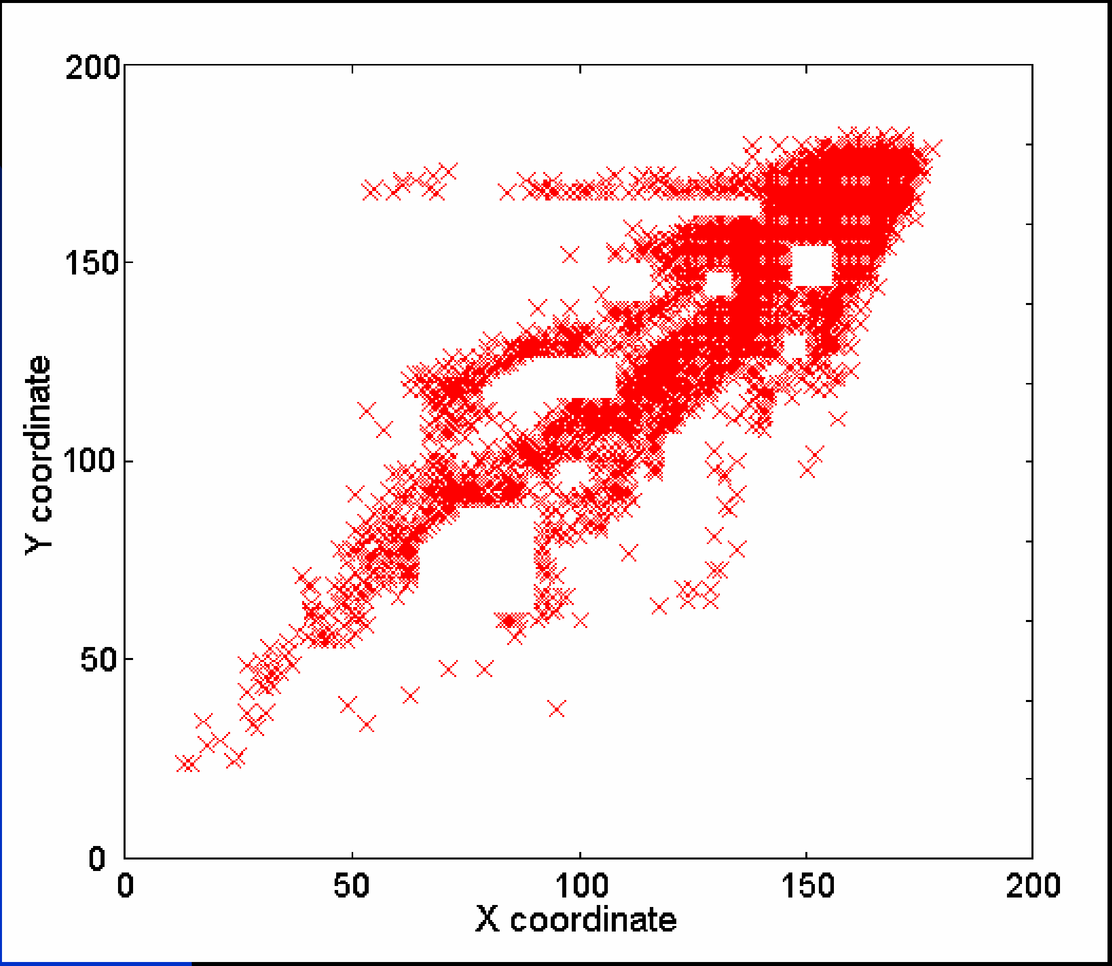
$$\frac{\Delta B}{\Delta t} = f(R, t, k_r, D)$$

# A convenient form is:

$$\left\langle \frac{\Delta B}{\Delta t} \right\rangle \propto R\, {k_r}^{E(D)}\, \Delta t^{-F(D)}, \quad E + F = 1$$

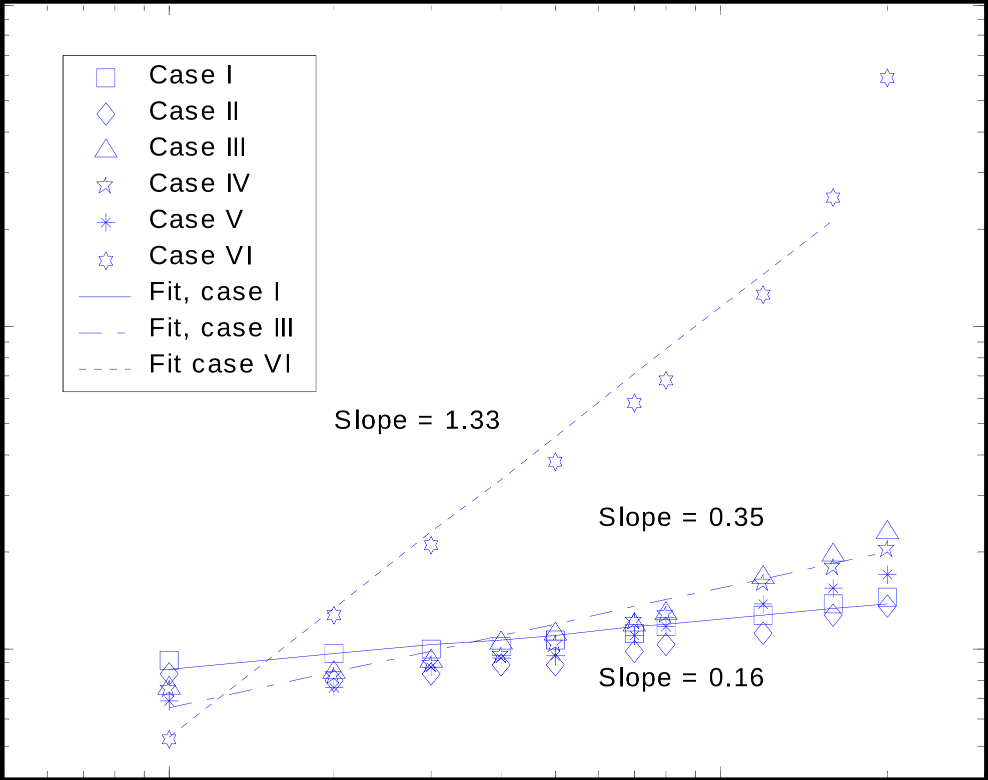
- Two parts: *k* and *t*
- Ensemble of runs with similar distribution of Red.
- Can choose by requiring a minimum casualty level.
- Reduces to the Lanchester equation.

# Fractal pattern (MOUT)



# The *k* part:

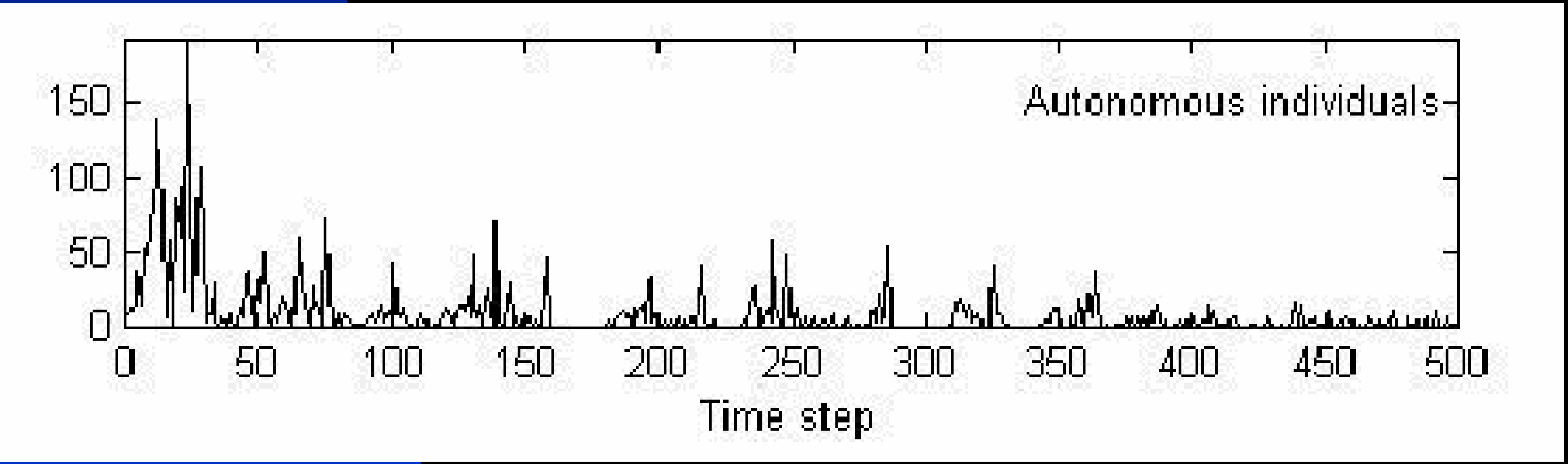
- Different patterns for different behaviours, implies differing attrition rates.



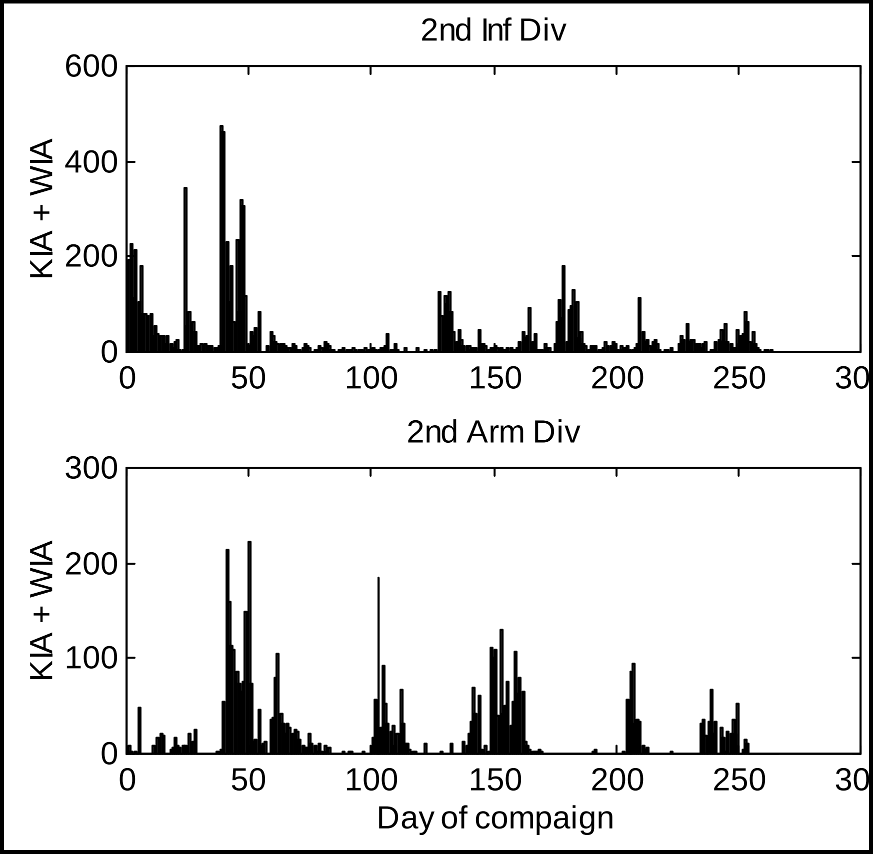
# The *t* part:

- Implies that the attrition function itself should have a specific temporal structure.
- Should be intermittent and clustered

  i.e. when it rains it pours.



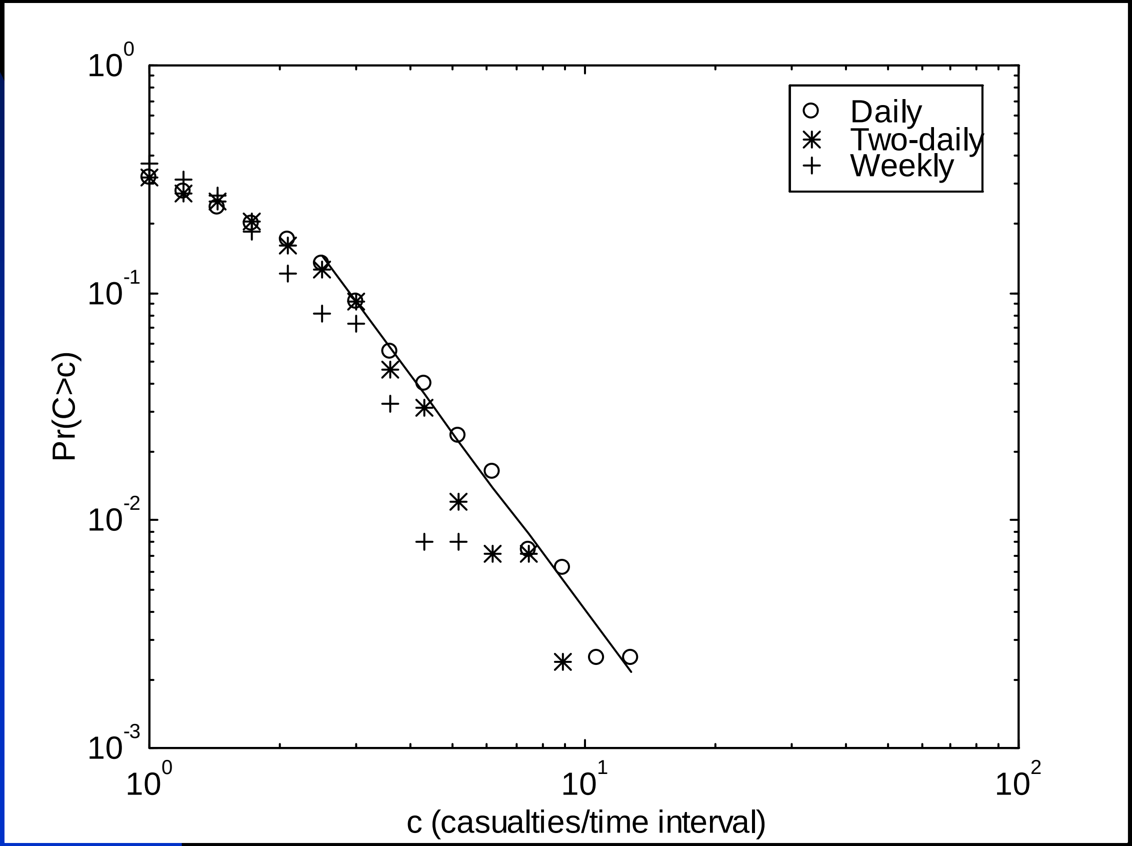
# Historical data confirms our hypothesis!



# Applications

Has implications for C2 and logistic loads etc.

$$c = \left( \frac{P}{1.68} \right)^{-0.4}$$



# Casualty estimation

| Percentile | Normalized estimate | Actual 1st Inf Div estimate (actual) | Actual 2nd Inf Div estimate (actual) | Actual 4th Inf Div estimate (actual) | Actual 2nd Arm Div estimate (actual) |
|---|---|---|---|---|---|
| 90% | 3.1 | 98 (92) | 110 (88) | 206 (186) | 61 (64) |
| 95% | 4.1 | 130 (100) | 145 (130) | 271 (253) | 81 (95) |
| 99% | 7.8 | 248 (159) | 278 (319) | 517 (470) | 154 (160) |
| Mean | 1.0 | 31.8 | 35.6 | 66.4 | 19.8 |

# Understanding historical results

$$C = (\text{Number of attackers/Number of defenders})^{0.685}$$

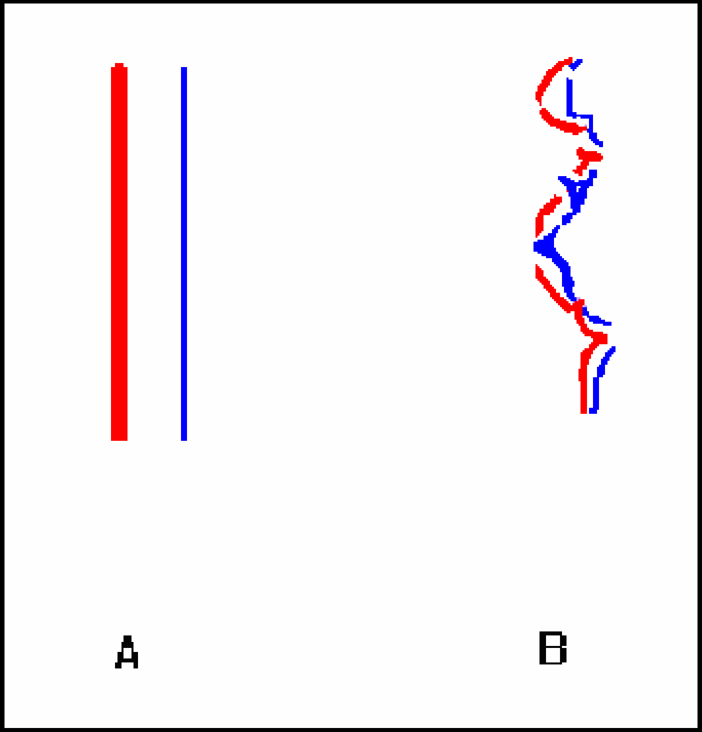
- Thornton (UK)
- Osipov (Russia)
- Helmbold (US)

Inconsistent with Lanchester!

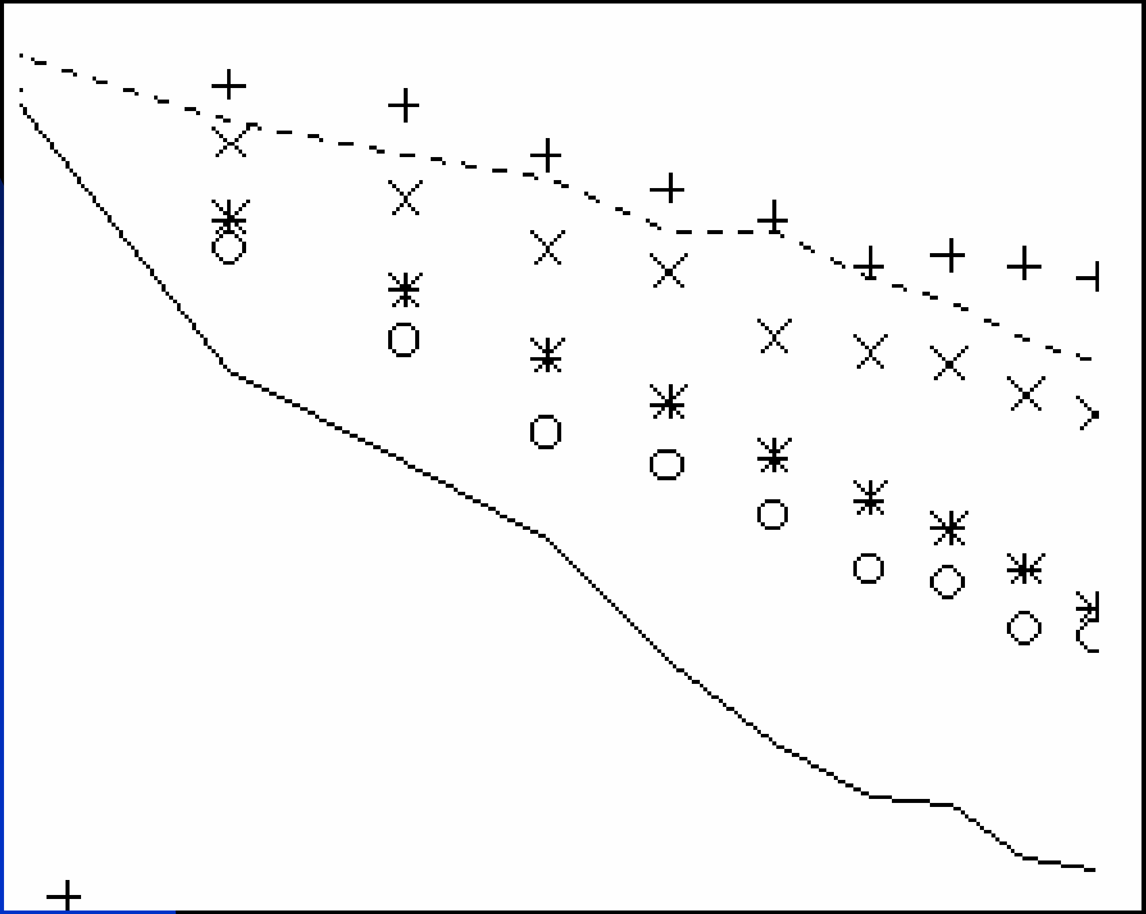
# Fractal idea

- Check with agent-based models
- Behaviour (tactics) causes battles to evolve in similar (but not exactly the same) ways
- Could there be a fractal attractor at work?

- Battles evolve into an attractor with the same fractal dimension for the same types of battles (related to ideas proposed by Jim Moffat)



# Find values for *D*:



# What this gives us

- Fractal nature of combat data tells us our models need to produce output consistent with fractals
- Thus, fractals provide a method by which we can judge if the complexity is being characterised properly by our models
- Can characterise sophisticated differences in forces by a single parameter!